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Title: slides for job interview

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- Quasiparticle interference of magnetic Weyl semimetal $CeBi$
- Massless Higgs mode in Fulde–Ferrell–Larkin–Ovchinnikov state
- Nonlinear dynamics of Majorana modes in topological Josephson junctions
- Research proposal in Aliroquantum

CeBi: Another magnetic Weyl semimetal ?

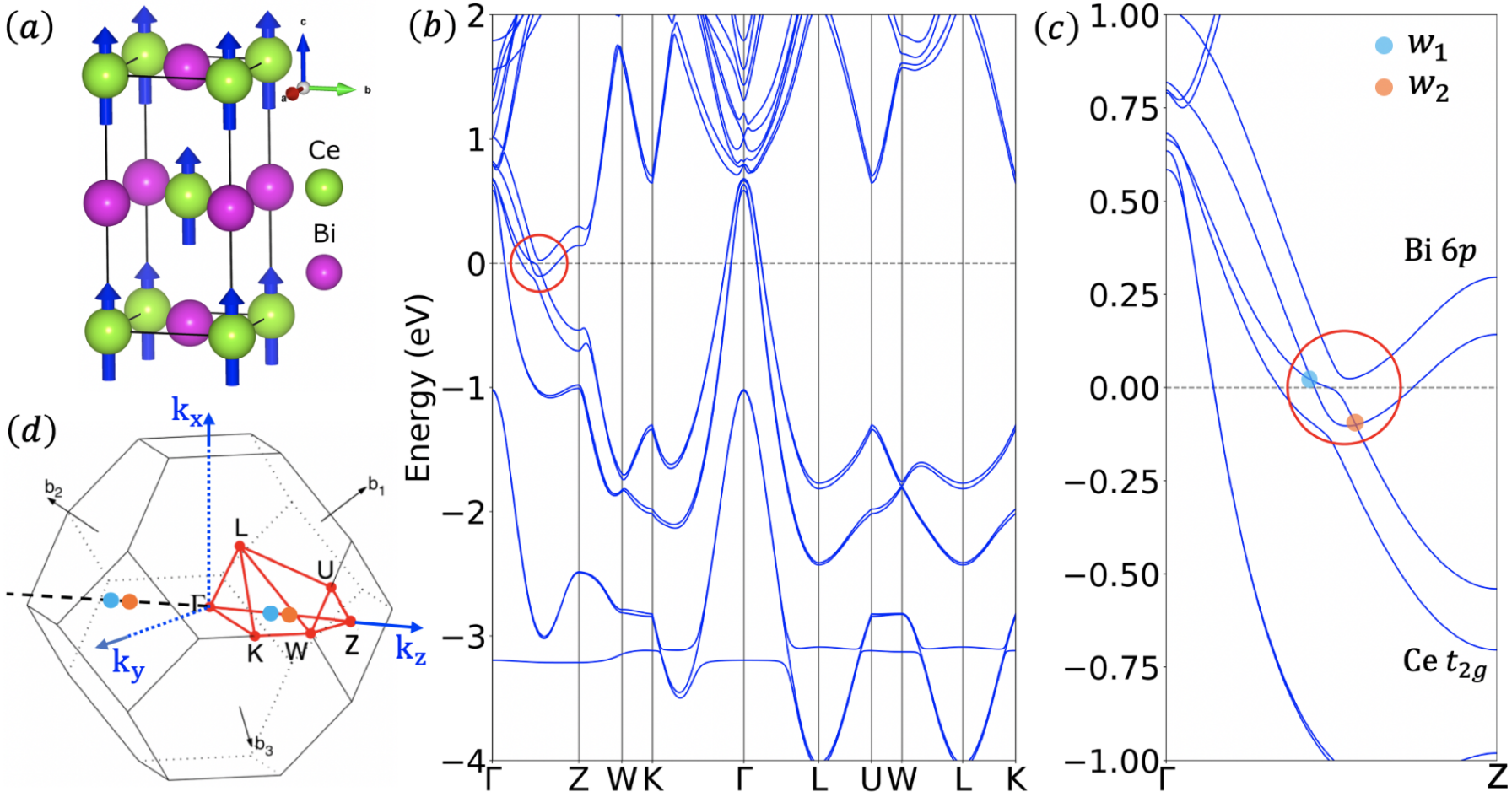
- ❑ Ferromagnetic CeBi with spin polarization along c-axis
- ❑ Two pairs of Weyl nodes on the momentum path $(0,0,k_z)$

Angular momentum:
2.92935 μ_B

Spin momentum:
-0.97470 μ_B

Total: 1.95 μ_B

in good agreement with experiment on similar material CeSb



$\mathrm{LDA + U}$
$U = 7.9eV$
$J = 0.69eV$
LAPW DFT
Wien2K

PRB 102, 235167 (2020)

arXiv:2012.14911

ZH, C. Lane, C. Cao, GX Zhi, Y. Liu, C. E Matt, B. Kuthanazhi, P. C. Canfield, D. Yarotski, A. J. Taylor, and JX Zhu

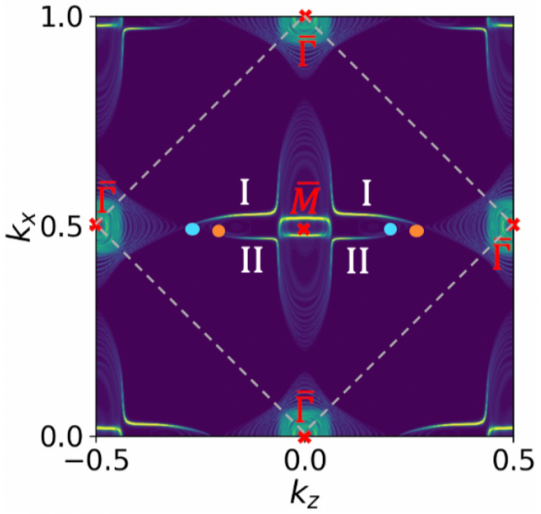
C. E Matt, Y. Liu, H. Pirie, N. C Drucker, N. H. Jo, B. Kuthanazhi, **ZH**, C. Lane, JX Zhu, P. C Canfield, J. E Hoffman

Spectral function and spin texture of 010 surface

❖ ab initio tight binding model

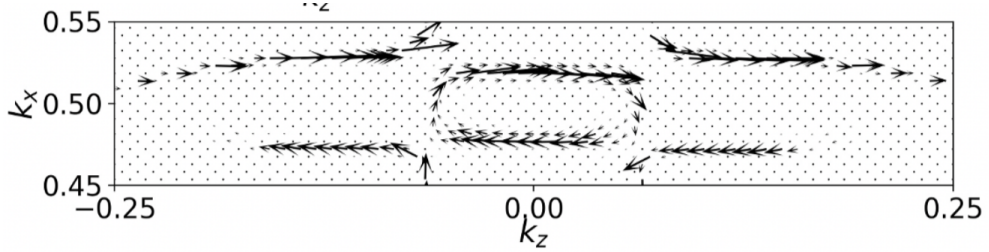
❖ Effectively 64 layers slab

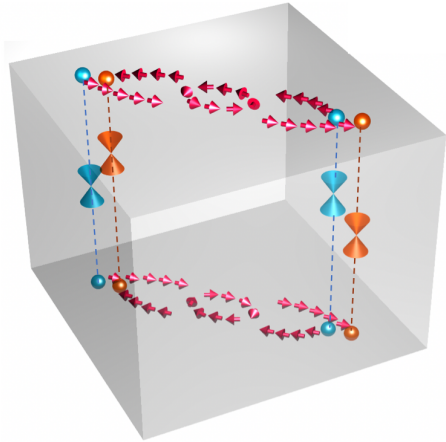
❑ Spectral function



Fermi arc
I and II

❑ Spin polarized Fermi arcs and spin vortex



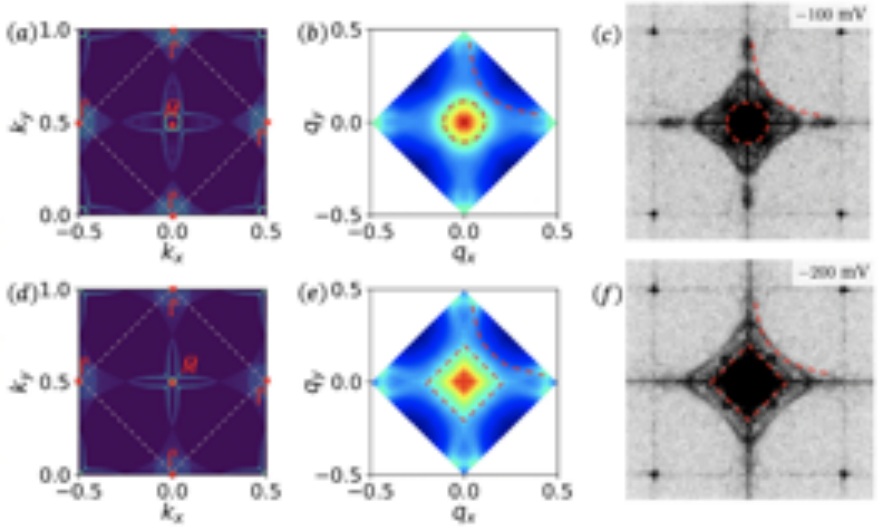


schematic

quasiparticle interference (QPI) pattern

$$\mathrm{QPI}(\mathbf{q},\omega) = \frac{i}{2\pi}\int \frac{d^2\mathbf{k}}{(2\pi)^2}\left[B(\mathbf{q},\omega) - B^*(-\mathbf{q},\omega)\right]$$

$$B(\mathbf{q},\omega) = Tr[G(\mathbf{k},\omega)T(\omega)G(\mathbf{k}+\mathbf{q},\omega)]$$



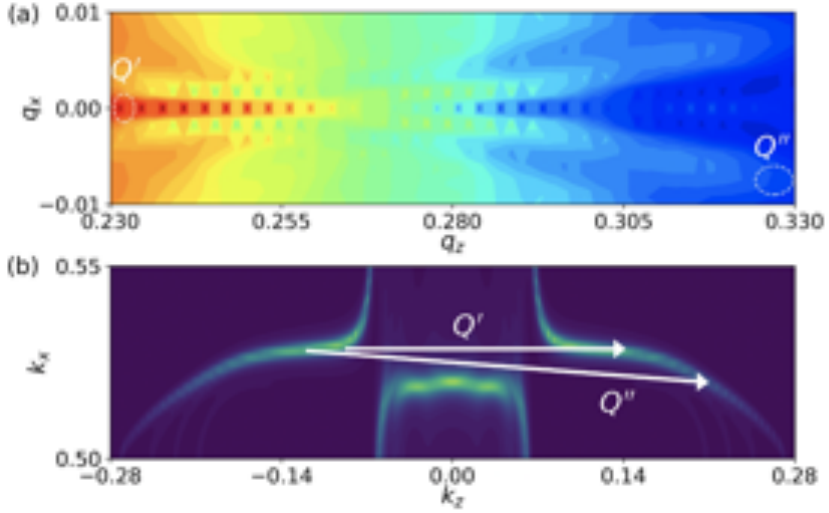
Bifurcation-shaped feature

$$T = \left[1 - (2\pi)^{-2} V_{imp}\int d^2\mathbf{k} G(k,\omega)\right]^{-1} V_{imp}$$

$$T = IV_{imp}$$

take $V_{imp} \to 0$

no inter-orbital or –spin scattering



$$\frac{4\pi}{a} = 1$$

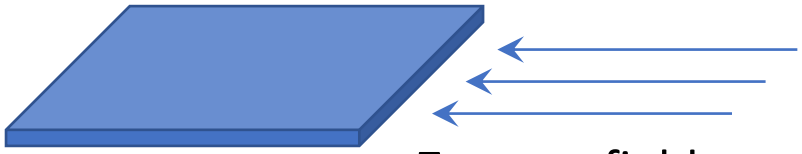
Expected signature of Weyl nodes in experiments

Massless Higgs Mode in Fulde–Ferrell–Larkin–Ovchinnikov (FFLO) states

❑ FFLO state

Thin superconducting film

Particle-hole space



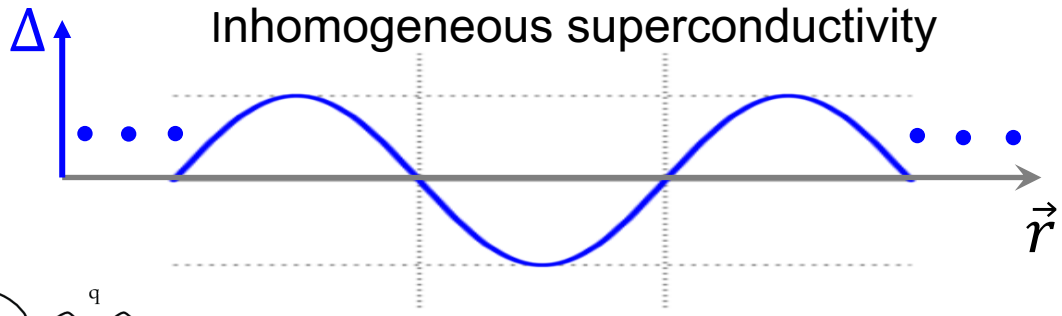
Zeeman field

$$H = \begin{bmatrix} \xi_k - \mu + V_z & \Delta \\ \Delta & -(\xi_k - \mu - V_z) \end{bmatrix}$$ V_z Zeeman energy

Cooper pairing at diferent momentum

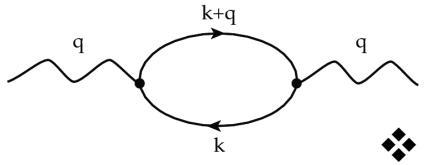
Paper in preparation

ZH, C. S. Ting, Jian-Xin Zhu, and Shi-Zeng Lin

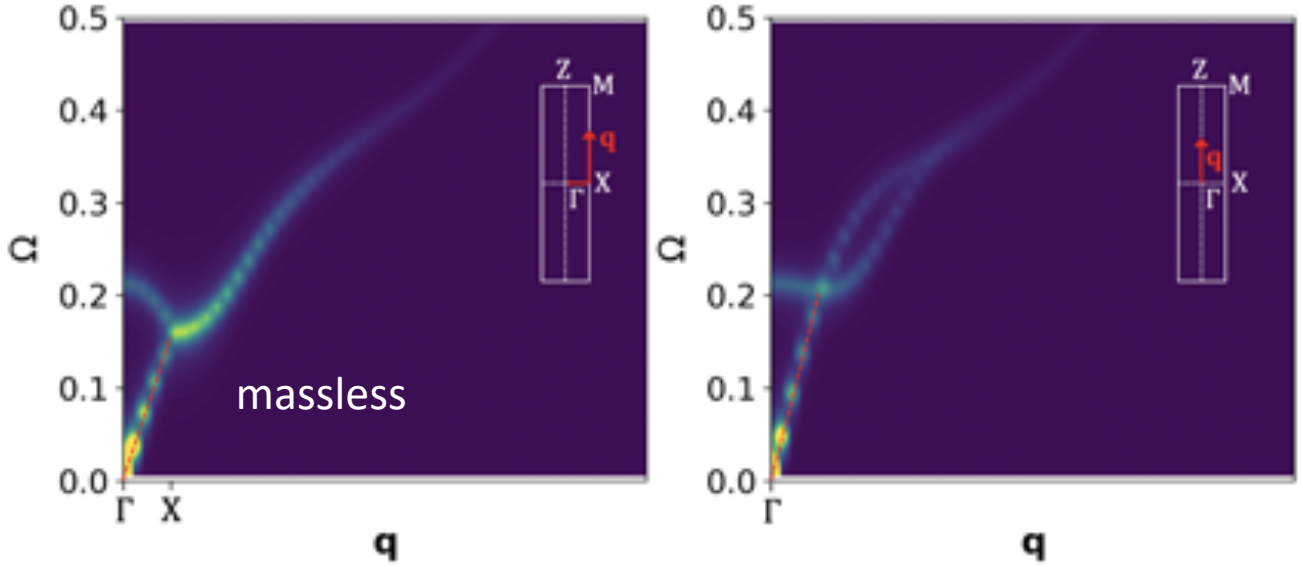


❑ Higgs mode

Action $S_2 = \int_0^\beta d\tau \int d^2r \frac{1}{g} s^2 + \frac{1}{2}\mathrm{Tr}(G_0 \sum G_0 \sum)$



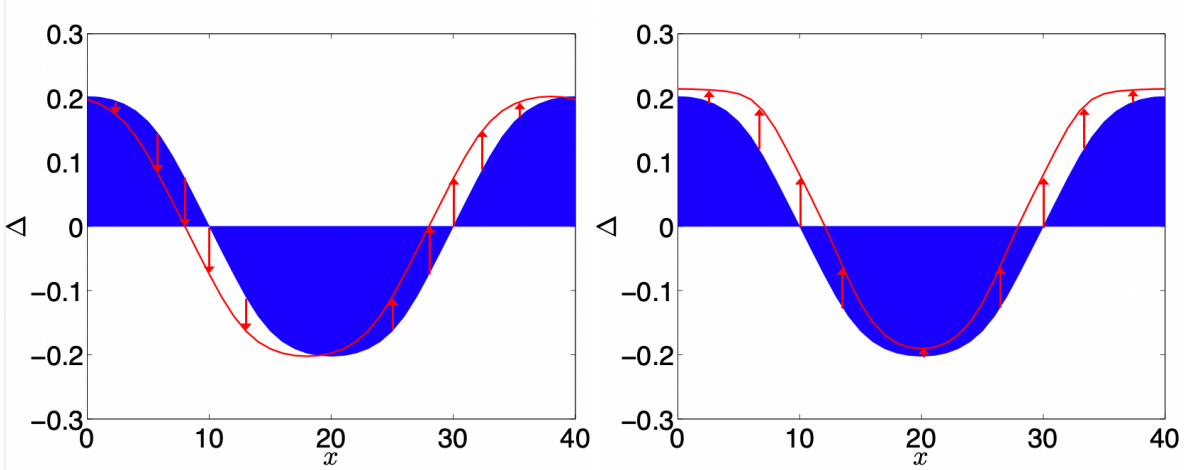
❖ Dispersion relation



Goldstone mode of broken translational invariance

= Higgs mode of superconducting gap functions

❖ Two fluctuation modes at Γ point

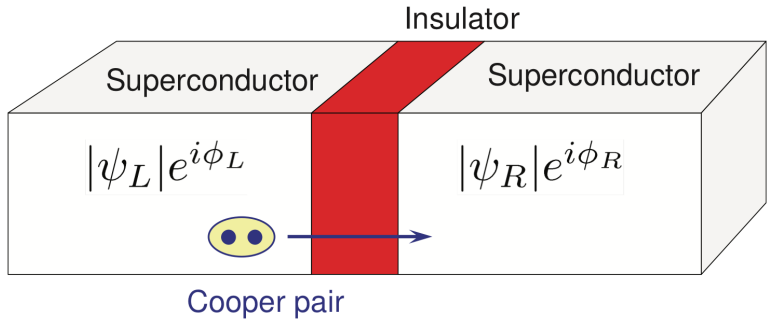


Goldstone mode is massless → massless Higgs mode

much easier to be observed experimenally than massive Higgs boson

Nonlinear dynamics of Majorana modes in topological Josephson junctions (TJJ)

❑ Conventional Josephson junction



DC Josephson effect:

$$J = I_c \sin\theta$$

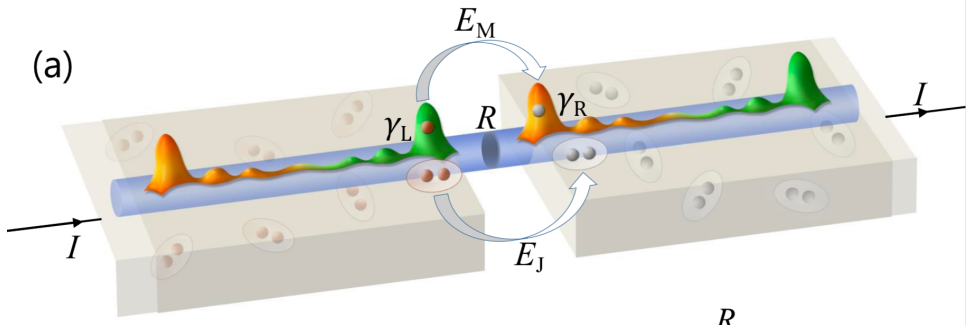
AC Josephson effect

$$\dot{\theta} = 2eV/\hbar$$

PRB 98, 134515 (2018) Jiajin Feng, **ZH (co 1st author)**, Zhi Wang, Qian Niu

PRB 101, 180504(R) (2020) Jiajin Feng, **ZH (co 1st author)**, Zhi Wang, Qian Niu

❑ Topological Josephson junction



Two coupled Majorana mode → single-electron tunneling

$$J = \pm I_c \sin\frac{\theta}{2} \qquad \begin{matrix} + \text{ for } |0\rangle \\ - \text{ for } |1\rangle \end{matrix}$$

L. Fu and C. L. Kane, PRB (2009)

❑ Superposition of $|0\rangle$ and $|1\rangle$

In real devices with finite size, γ_L and γ_R weakly couple with two outer Majorana modes

Coupled 4 Majorana modes ⟶ two-electron state

Even parity: $|00\rangle, |11\rangle$ Odd parity: $|01\rangle, |10\rangle$

Under either parity

$$H = \begin{pmatrix} E_M \cos\theta/2 & \delta \\ \delta & -E_M \cos\theta/2 \end{pmatrix}$$

We are the first to consider the effect of qubit rotation on Josephson current in TJJ

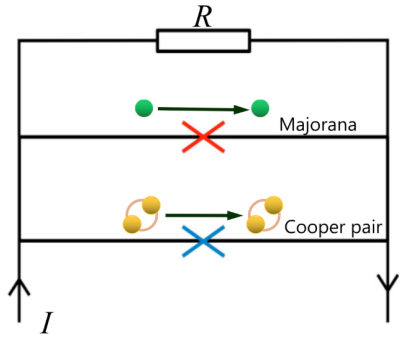
❑ Dynamical equations

Schrodinger equation

$$i\hbar \frac{d}{dt}\begin{pmatrix}\psi_0\\ \psi_1\end{pmatrix} = \begin{pmatrix}E_M\cos\theta/2 & \delta\\ \delta & -E_M\cos\theta/2\end{pmatrix}\begin{pmatrix}\psi_0\\ \psi_1\end{pmatrix}$$

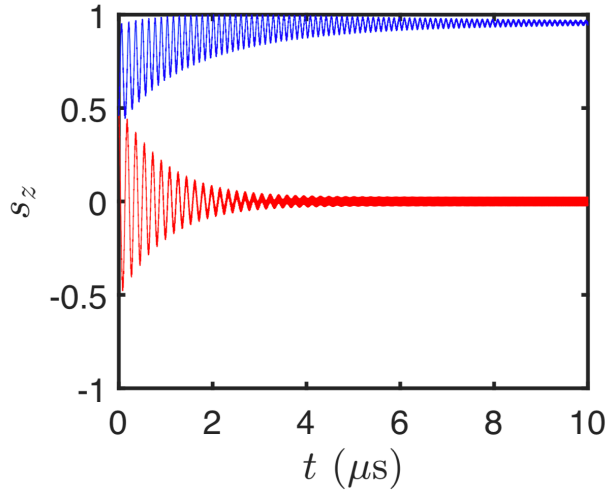
resistively shunted junction model

$$I = \frac{\hbar\dot{\theta}}{2eR} + I_{c1}\sin\theta + I_{c2}\langle s_z\rangle \sin\frac{\theta}{2}$$

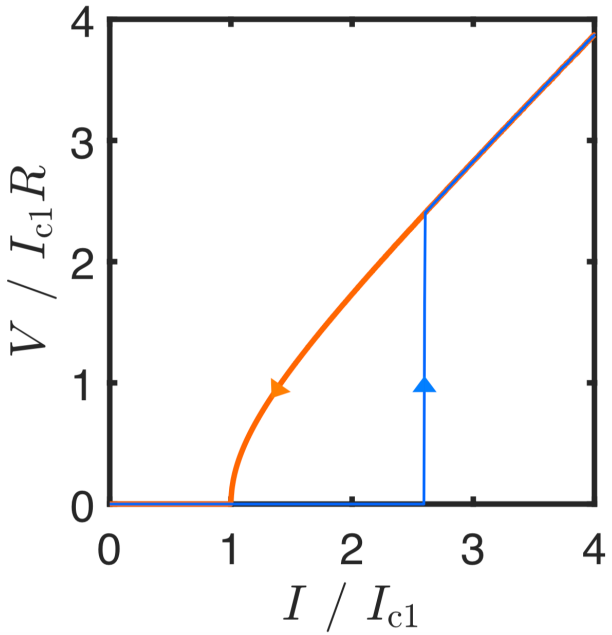


$$\langle s_z\rangle = (|\psi_1|^2 - |\psi_0|^2)$$

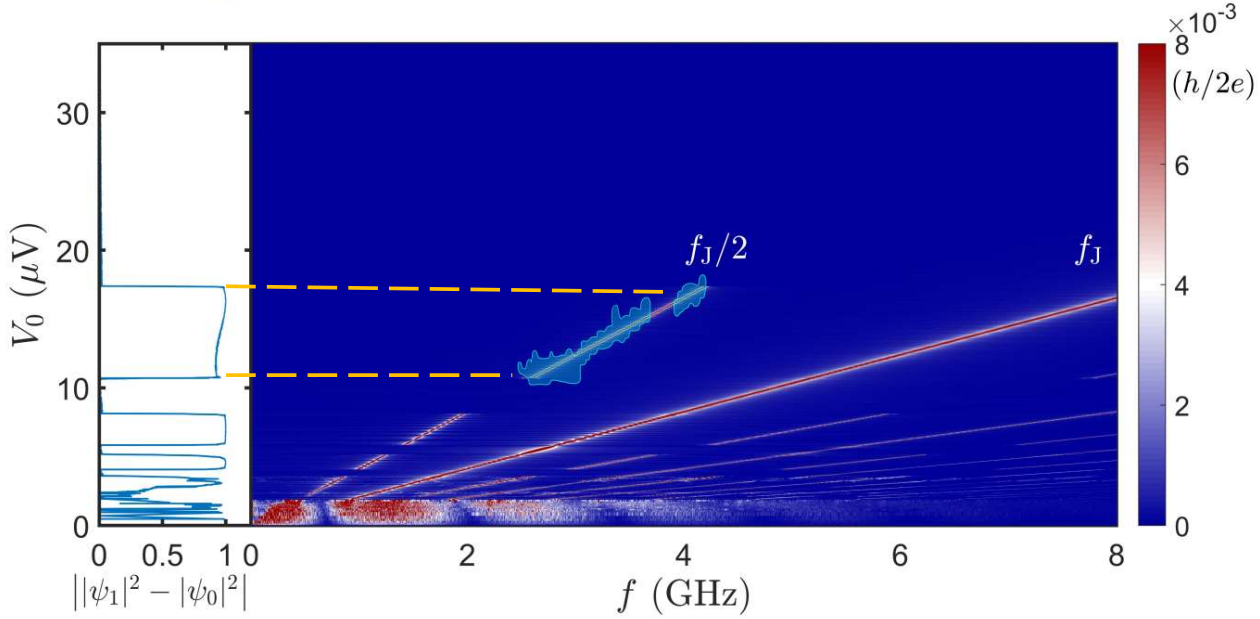
❑ Fixed point of $\langle s_z\rangle$ depending on injected current



❑ Hysteresis in I-V curve



❑ Interrupted radiation line



Other ongoing works:

1) Quantum quench between topological superconducting state and trivial superconducting state.
2) Dark matter absorption and scattering in topological matters.

Research proposal in field of quantum computation:

1) Study quantum dynamical phase transition between topological trivial and nontrivial state on IBM Q system
2) Study quantum algorithms to prepare mean-field wave functions in quantum computers
3) Develop software based on ab-initio tight models in quantum computers